Appendix 6. VPA Projection Results

Methods

A 2-fleet, tuned VPA was implemented, where the catch at age (CAA) for fleet 1 represented total directed catch and discards for Handline, Longline, and Recreational fisheries, and fleet 2 represented shrimp bycatch. Modeled ages were 0-15+ or 1-15+. Natural mortality at age was: M_0=1.0, M_1=0.6, $M_{2\text{-}15+}$=0.1. A moderate penalty was imposed to link selectivities ($s_{a,y}$) in the final 3 years. The estimate of annual fishing on the oldest age group ($F_{15+,y}$) was constrained to be equal to the estimate of $F_{14,y}$ for all years. Five regional indices (units) were used for tuning, where the region was Gulfwide, Eastern Gulf, or Western Gulf: MRFSS (numbers), Video (numbers), Larval (reproductive biomass—used as index of SSB), Fall Trawl Survey (numbers), Summer Trawl Survey (numbers). For cases where the modeled age of recruitment was 1, the Fall Trawl Survey was not used as it indexes age 0 fish. All indices were given equal weighting.

The VPA estimates of fishing mortality at age and year, and estimated abundance at age and year, were used in a set of factorial projections for the years 2004-2032. The following specifications were common to all projections:

- selectivity was fixed at the geometric mean of the last 3 years (2001-2003)
- with respect to benchmark estimation, all projections represent the "linked" scenario
- discard proportion for the directed fleet was fixed at the geometric mean of the last 3 years (2001-2003)
- the last 3 years of recruitments (2001-2003) were replaced with values predicted from the fitted Beverton-Holt
- F values in 2004-2006 were set to the 2003 estimates
- TAC, directed F, and bycatch reduction scenarios were implemented in 2007

Results

Updated benchmarks for the VPA projections are given in Table 1. Because the VPA modeling framework does not explicitly allow for closed seasons, the estimates of MSY include the weight of closed season discards by the directed fleet. Weights of 0 at all ages were specified for the shrimp bycatch fleet, so the MSY does not include any mass due to shrimp bycatch.

<u>Age 0</u>

Model responses to reduction in shrimp effort varied by region. Isopleths for transitional SPR (tSPR) were less steep in the east models, suggesting less sensitivity to reductions in shrimp effort. If half of the 9.12 million pound Gulfwide TAC (i.e. 4.56 mp) is applied in the east model, then shrimp effort would have to be reduced by about 60% to achieve a 20% tSPR by 2032 (Fig. 1, 2). A tSPR of 30% in 2032 is not achievable, even if shrimp effort were eliminated. With no shrimp reduction, a 4.56 TAC achieves 0.2 S/S_{MSY}, while a TAC of about 3 achieves S/S_{MSY}=1.0. The western gulf model suggests that the stock can support a larger TAC than the eastern gulf. If shrimp effort is eliminated, a TAC of up to 20 mp would achieve tSPR of 0.3; if shrimp effort is not reduced, a TAC of 12 mp achieves tSPR=0.2 by 2032. With no shrimp effort reduction, a TAC of about 5 mp achieves S/S_{MSY}=1.0. In the Gulf-wide model, a TAC of 9.12 mp yields tSPR values that are ≥0.3. With no shrimp effort reduction, a TAC of about 18 mp achieves S/S_{MSY}=1.0. (Fig. 1, 2).

With respect to isopleths where effort reductions in both fleets were explored, East model runs that apply 40-85% of current fishing effort would achieve tSPR in the range of 20-30% for all shrimp reduction scenarios (Fig. 3, 4). Current directed fishing effort would produce tSPR of 15-20% by 2032. The directed fishery realizes very little gain in yield from reducing shrimp effort if current fishing effort is reduced by half (or more)—even if shrimp effort is completely reduced. In the west, current directed fishing effort maintains tSPR ≥ 20% for all shrimp effort reductions. Fishing at levels less than 30% of current directed effort does not lead to substantial gains in yield from reduced shrimp

effort. In the Gulf, current directed fishing effort maintains tSPR ≥ 20% for all shrimp effort reductions. Gains in yield resulting from reduced shrimp effort are marginal if fishing effort is less than 30% of current levels (Fig. 3,4).

Age 1

In the east, applying a TAC of 4.56 mp does not achieve a tSPR of 20% by 2032, although TACs in the range of 3-3.5 mp do (Fig. 5, 6). A TAC of <3 mp is needed to achieve S/S_{MSY}=1.0. In the west, a TAC < 11 mp always maintains tSPR ≥ 20%; larger TACs in the range of 12-15 mp are only possible with shrimp effort reductions > 40%. A TAC of approximately 7.5 mp is needed to achieve S/S_{MSY}=1.0. In the gulf-wide model, TACs in the range of 12.5-15.5 mp generally maintain tSPRs of 20-30%; larger TACs are possible only if shrimp effort is greatly reduced. A TAC of about 12 mp is needed to achieve S/S_{MSY}=1.0.

With respect to isopleths where effort reductions in both fleets were explored, East model runs with directed fishing at 80-85% of current levels would ensure tSPR ≥ 20% for all shrimp effort reduction scenarios, while fishing at <40% of current levels shows little gain in yield from shrimp effort reduction (Fig. 7, 8). In the west, current fishing effort can maintain tSPR of at least 20% for all shrimp effort reduction scenarios. Fishing at 40% or less of current levels shows little yield gain from shrimp effort reduction. In the gulf-wide model, current fishing effort can maintain tSPR of at least 20% for all shrimp effort reduction scenarios, while fishing at 40% or less of current levels does not show substantial yield gains from reduced shrimp effort.

Table 1. Benchmarks for VPA runs.

MEASURE	Gulf age 0 high M R0 est	East age 0 high M R0 est	West age 0 high M R0 est	Gulf age 1 high M R0 est	East age 1 high M R0 est	West age 1 high M R0 est
F at MSY	0.33	0.20	0.41	0.44	0.29	0.52
MSY	27100	4183	13710	13990	3041	8992
Y/R at MSY	0.23	0.33	0.20	0.66	0.84	0.52
S/R at MSY	0.39	0.38	0.38	0.97	0.85	0.97
SPR AT MSY	0.34	0.33	0.33	0.32	0.28	0.32
SSB AT MSY	45390	4855	26280	20790	3074	16730
F at max. Y/R	0.35	0.23	0.41	0.44	0.29	0.52
Y/R max.	0.24	0.33	0.20	0.66	0.84	0.52
S/R at Fmax	0.37	0.32	0.38	0.97	0.85	0.97
SPR at Fmax	0.32	0.28	0.33	0.32	0.28	0.32
SSB at Fmax	42580	4032	26280	20790	3074	16730
F 0.1	0.27	0.17	0.32	0.34	0.22	0.40
Y/R at F0.1	0.23	0.32	0.19	0.64	0.81	0.51
S/R at F0.1	0.48	0.44	0.49	1.27	1.17	1.26
SPR at F0.1	0.42	0.38	0.43	0.42	0.38	0.41
SSB at F0.1	56040	5714	33810	27090	4221	21700
F 20% SPR	0.50	0.29	0.60	0.63	0.37	0.72
Y/R at F20	0.22	0.32	0.18	0.62	0.82	0.50
S/R at F20	0.23	0.23	0.23	0.61	0.62	0.64
SSB at F20	25740	2731	15990	13100	2229	10900
F 30% SPR	0.37	0.22	0.45	0.46	0.27	0.55
Y/R at F30	0.23	0.33	0.20	0.65	0.84	0.52
S/R at F30	0.34	0.35	0.34	0.92	0.92	0.92
SSB at F30	39550	4362	23900	19620	3333	15790
F 40% SPR	0.28	0.16	0.34	0.35	0.21	0.42
Y/R at F40	0.23	0.32	0.19	0.64	0.80	0.51
S/R at F40	0.46	0.46	0.46	1.22	1.23	1.23
SSB at F40	53480	5993	31890	26140	4446	21050

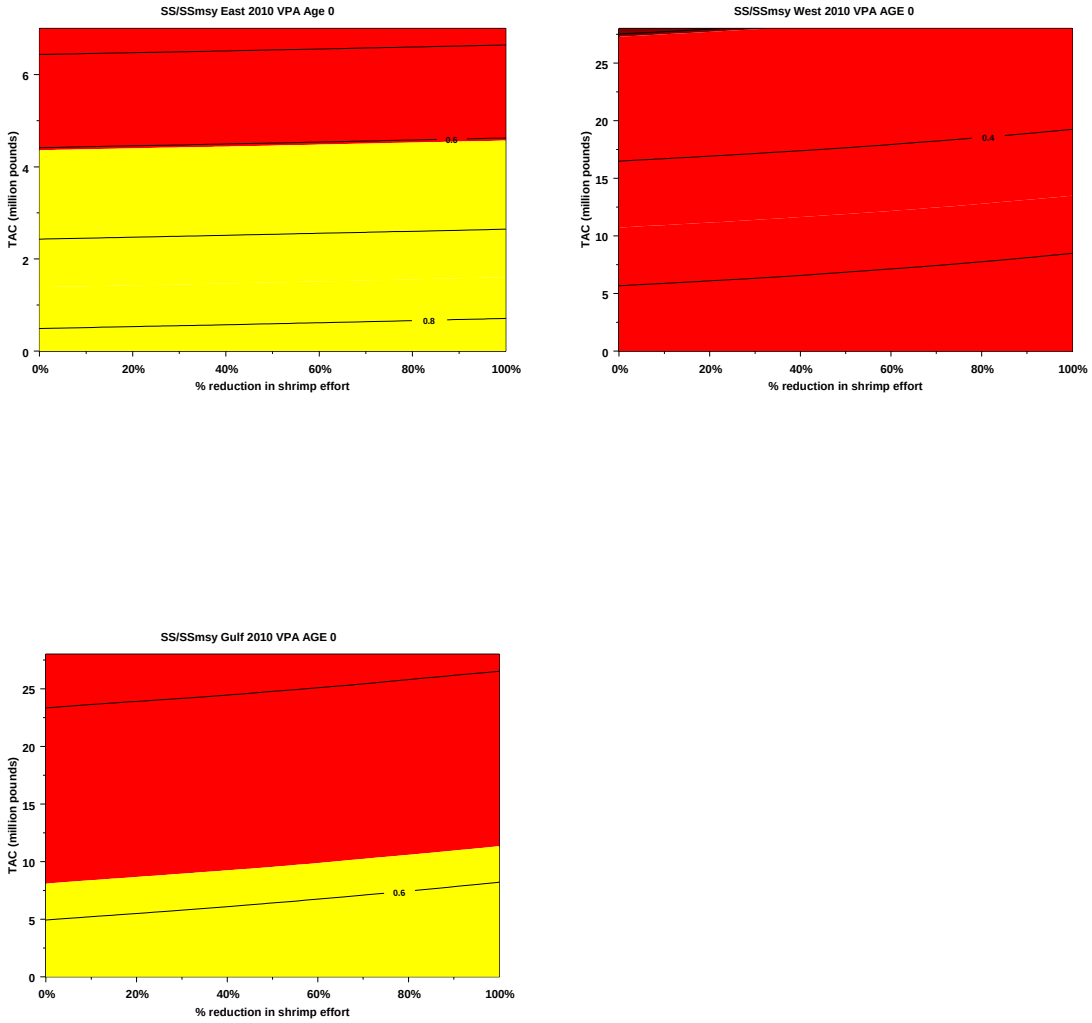


Figure 1. Projected isopleths of tSPR, $SS./SS_{MSY}$ resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. $SS./SS_{MSY}$ is overlayed as lines on the color contours.

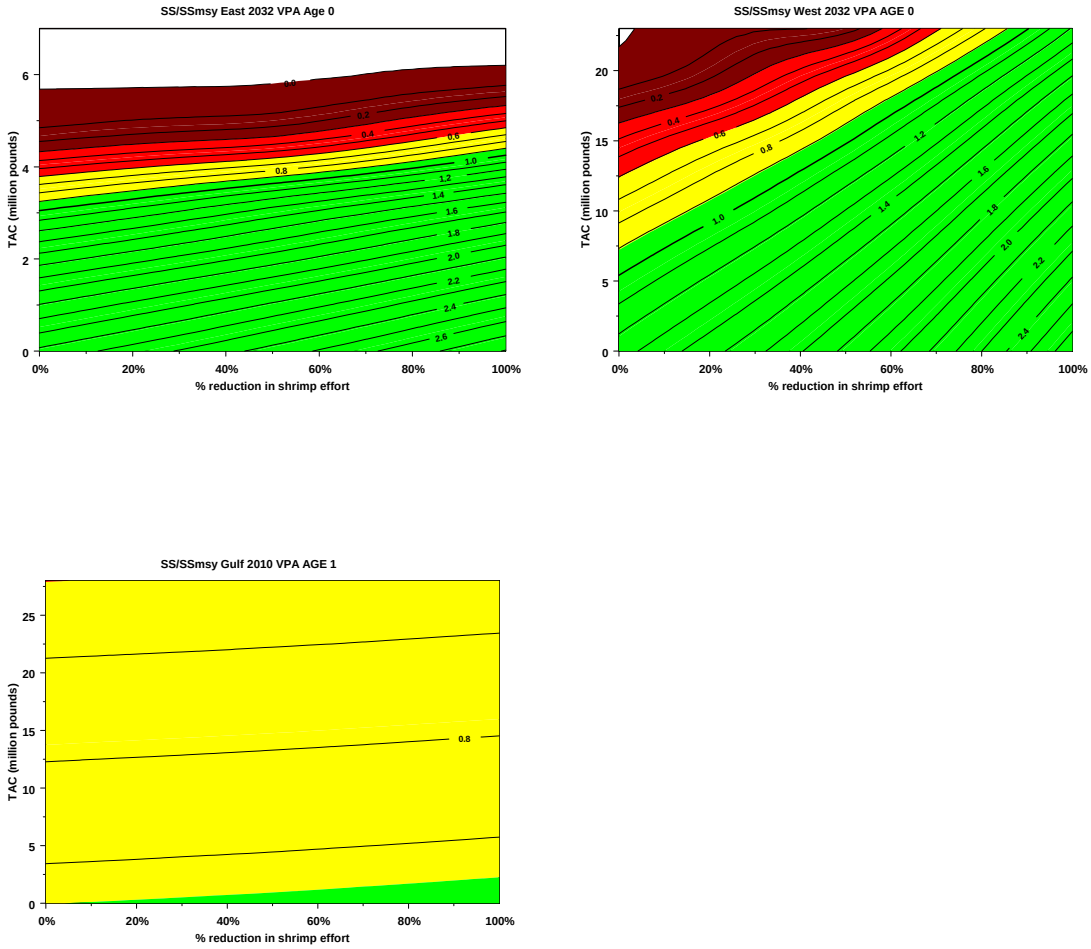


Figure 2. Projected isopleths of tSPR, $SS./SS_{MSY}$ resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. $SS./SS_{MSY}$ is overlayed as lines on the color contours.

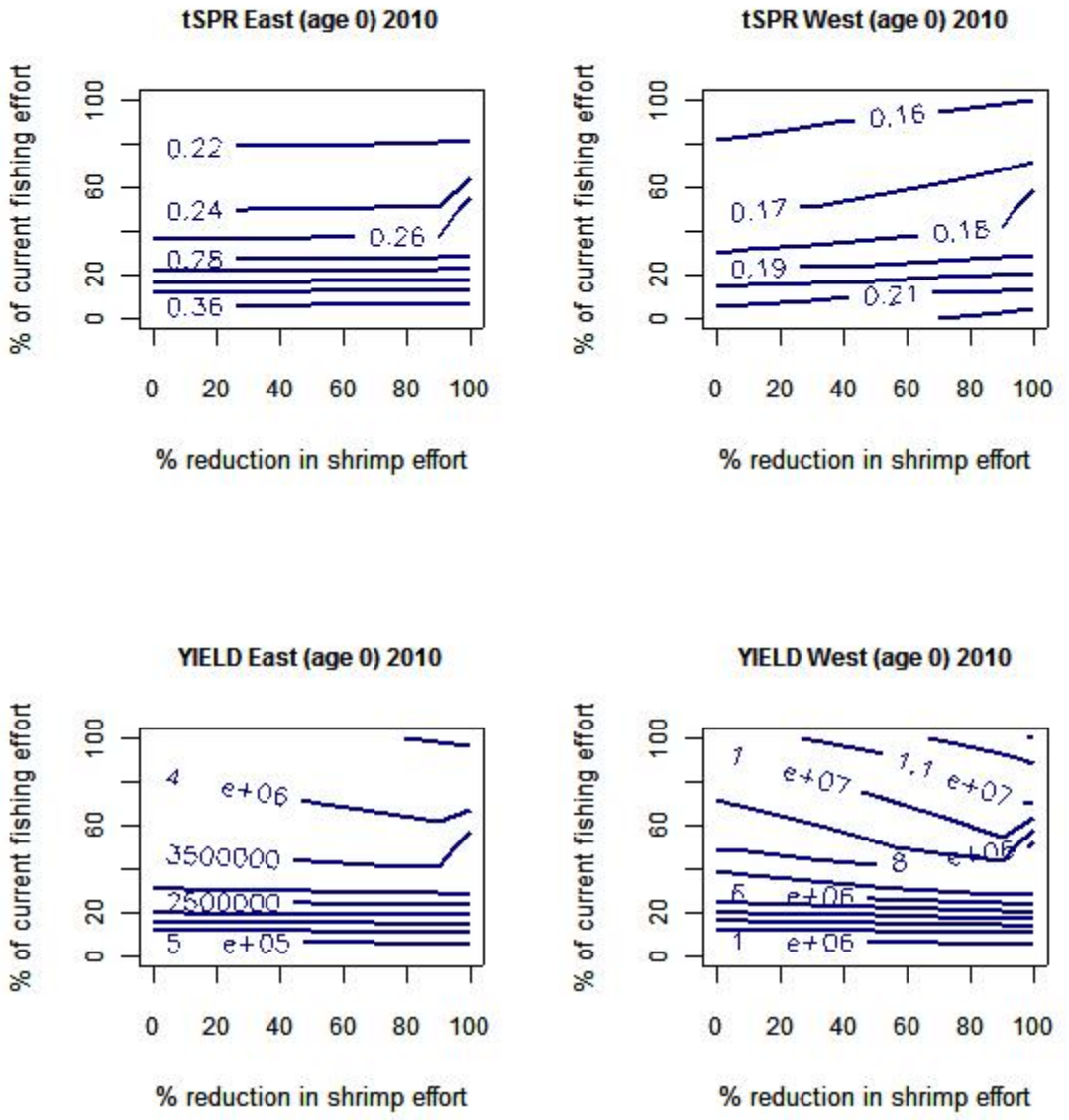
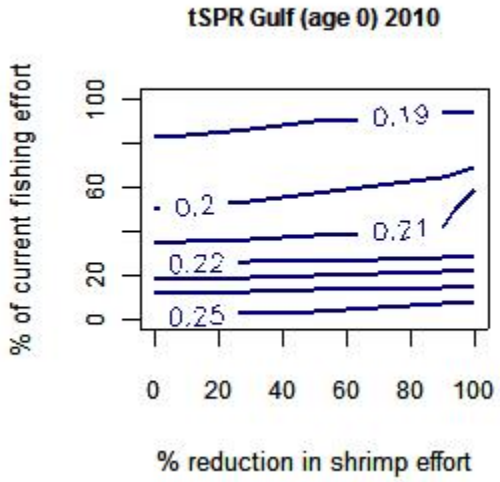
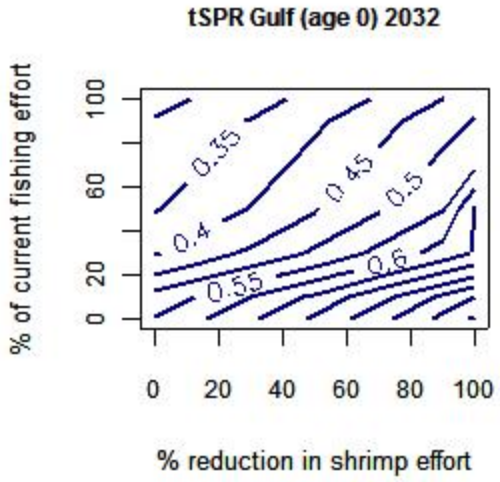


Figure 3. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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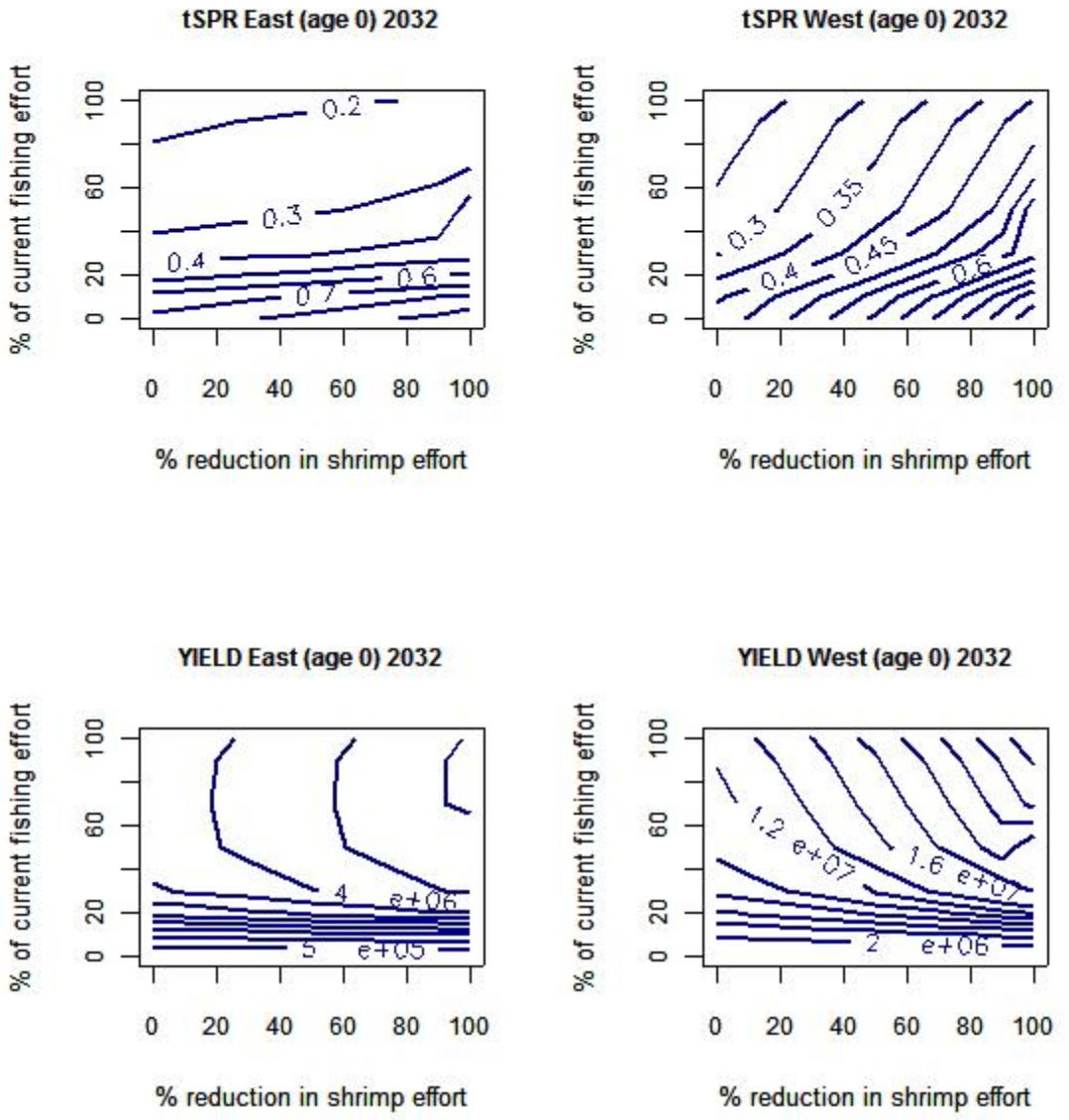
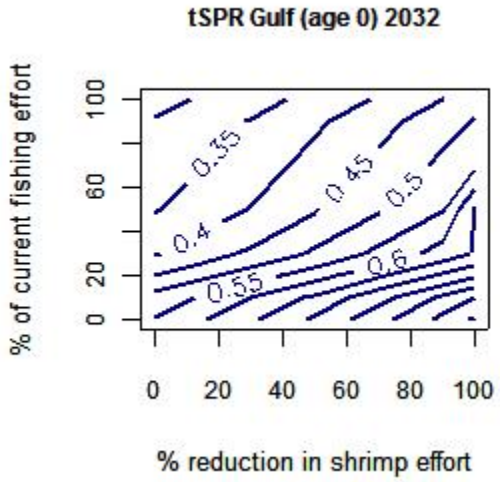
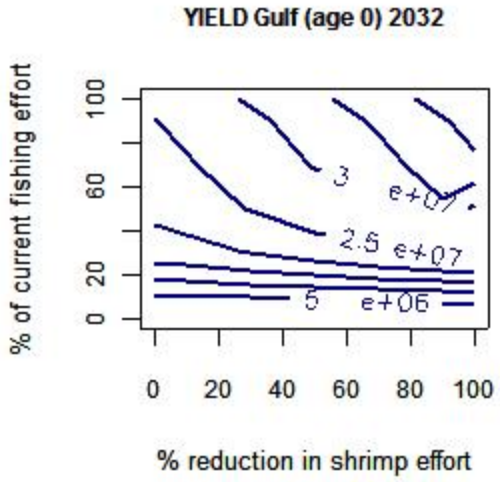


Figure 4. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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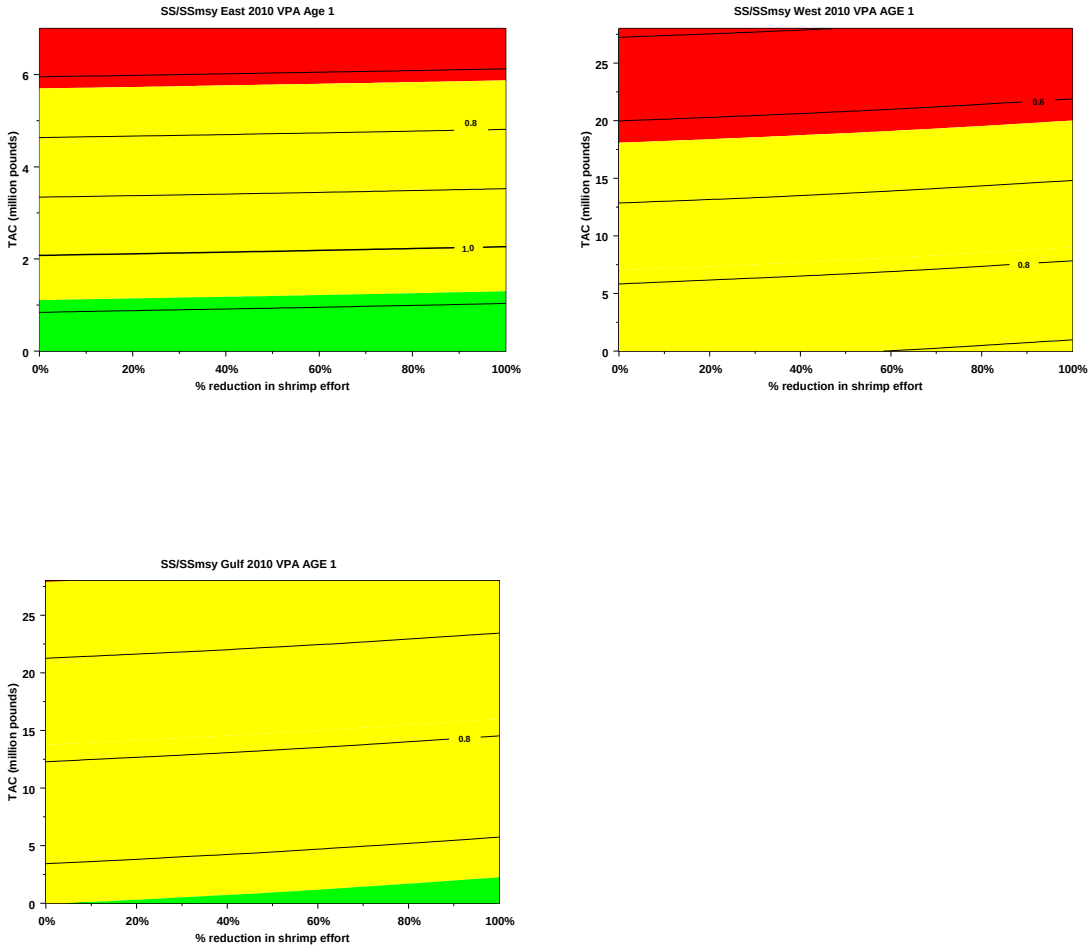


Figure 5. Projected isopleths of tSPR, $SS./SS_{MSY}$ resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. $SS./SS_{MSY}$ is overlayed as lines on the color contours.

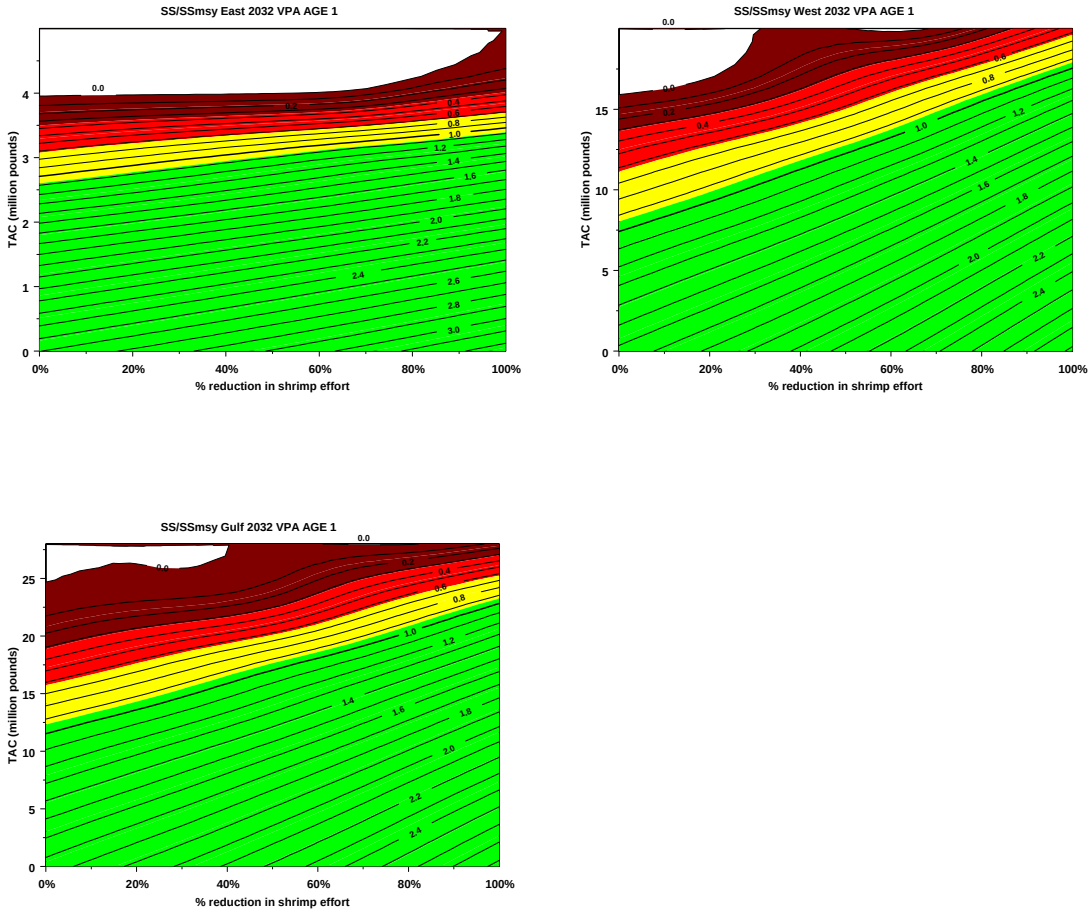


Figure 6. Projected isopleths of tSPR, $SS./SS_{MSY}$ resulting from TAC on the directed fishery and effort reduction for the shrimp fishery. Color contours indicate the tSPR level. Dark red indicates tSPR < 0.1, red indicates tSPR of 0.1-0.2, yellow indicates tSPR of 0.2-0.3, and green indicates tSPR >0.3. $SS./SS_{MSY}$ is overlayed as lines on the color contours.

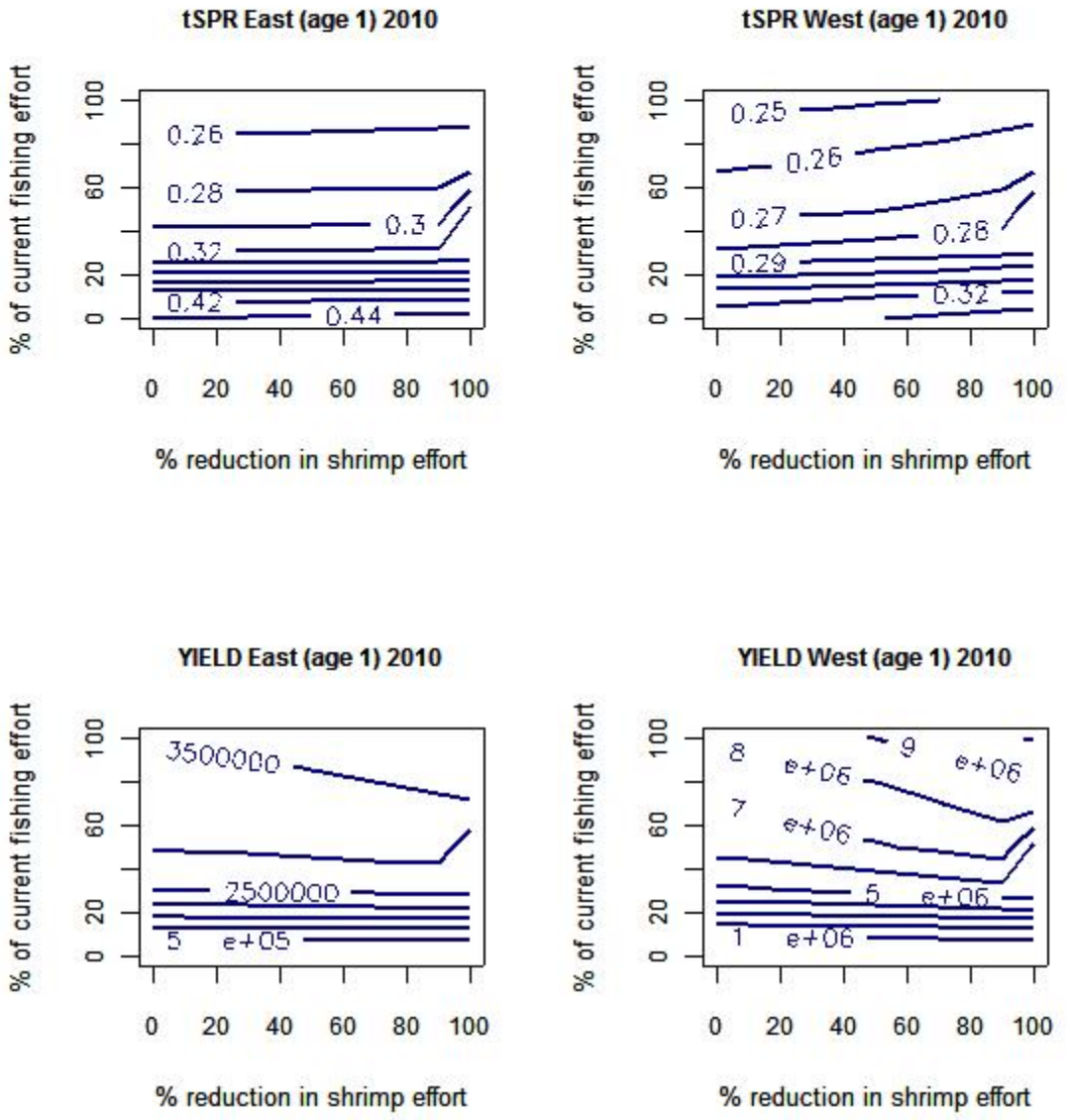
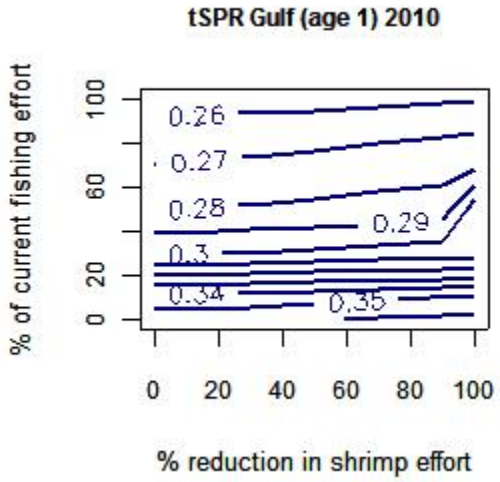
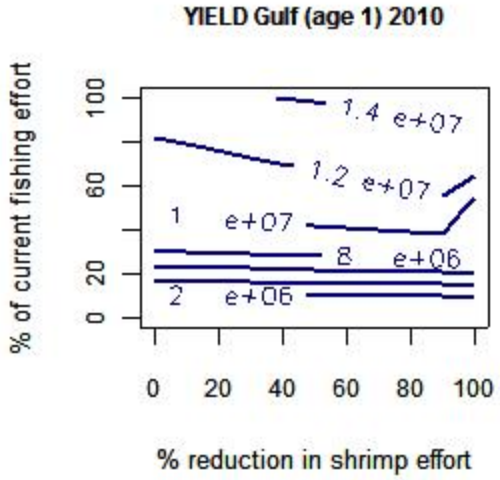


Figure 7. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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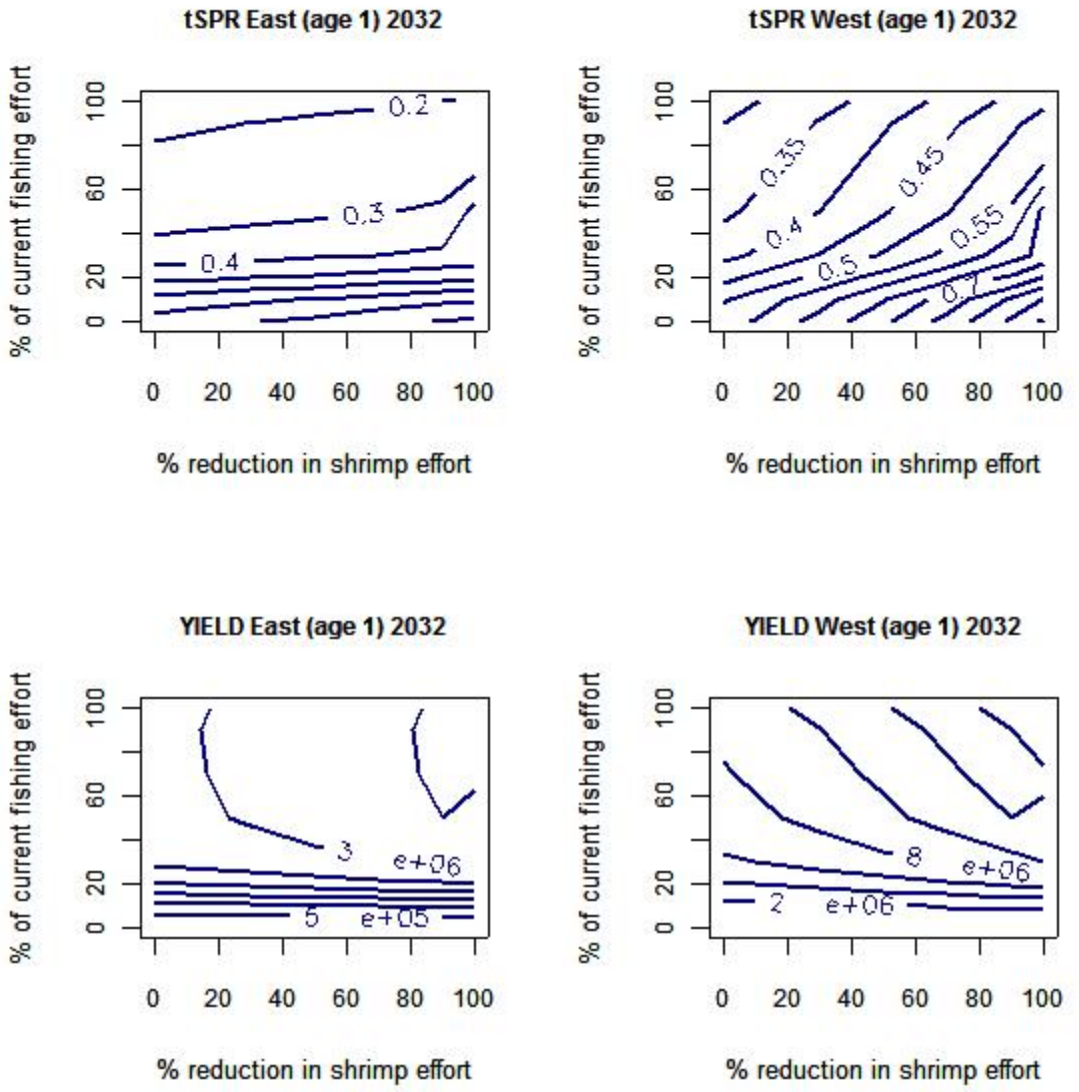
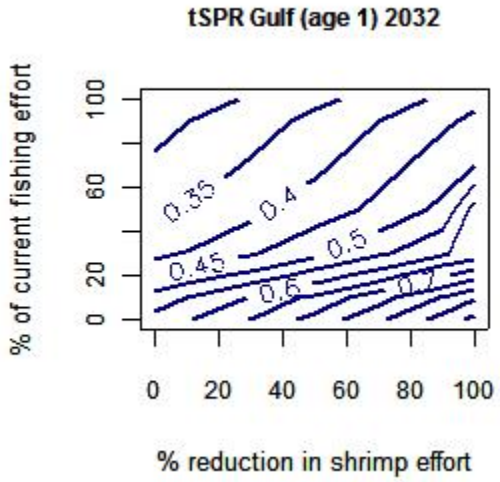
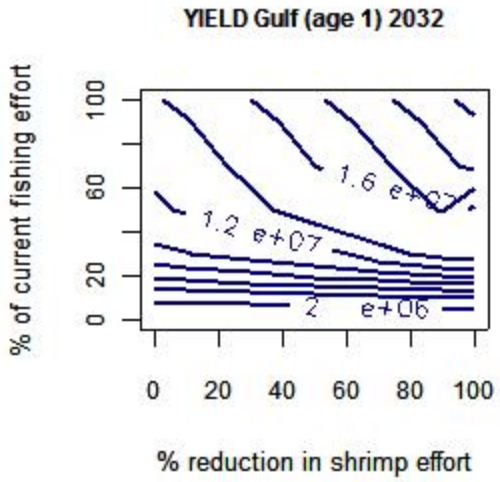


Figure 8. Projected isopleths of tSPR and yield to the directed fishery resulting from reductions in effort by the directed fishery and the shrimp fishery.





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